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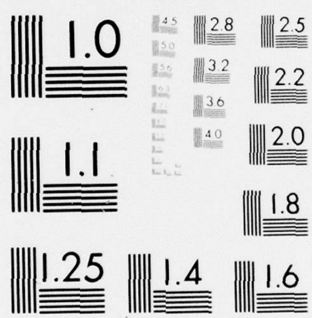

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EXPERIMENTAL ASSESSMENT OF MONOCULAR AND BINOCULAR VISION

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EXPERIMENTAL ASSESSMENT OF MONOCULAR AND BINOCULAR VISION

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Summary

Subjective tests using monocular and binocular vision ~~have been~~ were carried out to measure detection, acuity and recognition capabilities over a range of ambient luminances from 4.7×10^{-5} (.000047) to 7.1 Cd M^{-2} (Cd/sq m.).

Maximum binocular superiority is evident in the region of contrast threshold, the binocular threshold being as much as 30% lower than either of the monocular thresholds.

The ratio of binocular : monocular acuity is much lower for high contrast targets, binocular superiority being about 6% at high luminance. This figure steadily increases with reducing contrast and luminance.

The practical significance of the results is that binocular instruments have a maximum advantage over monoculars under low luminance conditions when the observer is attempting to acquire low contrast targets.

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1. INTRODUCTION

1.1 When designing a new direct vision instrument the optical designer has a number of parameters (magnification, field of view, size of object glass, amount of eye-relief, etc.) which he can vary to produce an optimised system for a given application. He is invariably limited by the size, weight and cost of the final system and a major factor is whether to design the instrument as a monocular or binocular system. The object of the work described in this report was primarily to give the optical designer sufficient information to enable him to base his choice on experimental evidence rather than subjective judgement or simple tradition.

1.2 A comparison between monocular and binocular viewing through optical instruments could be undertaken on the basis of

a. optical design

b. mechanical construction of the two types of instrument

c. physiology of the human visual process.

Both a. and b. can be considered on a theoretical basis and both would place the binocular at a disadvantage. The binocular requires twice the amount of glass, twice the amount of assembly and optical alignment; it requires an additional collimation procedure between the individual limbs and contains double the number of components which can develop faults and therefore require extra optical maintenance. Mechanically the binocular has certain disadvantages. Assuming equal optical parameters the binocular is both heavier and bulkier than its monocular counterpart. The binocular requires more mechanical maintenance and is vulnerable to loss of collimation by shock which invariably means that it has to be constructed more ruggedly. It usually requires an adjustment facility to allow for subjective variation in interocular separation.

1.3 A theoretical comparison between monocular and binocular viewing associated with the human visual system is only possible in a few very limited cases, owing to the lack of relevant experimental data. However, it is in this respect that binocular vision could be expected to show superiority over monocular viewing The very nature of the human eye renders a purely physiological study impossible using currently available technology. A statistical psychophysical solution was therefore chosen for the following reasons:

a. the complexity of the interocular connections renders any attempt at physical modelling impossible with present experimental methodology,

b. there is a large variation in the behaviour of the eye-brain systems of different individuals; even between individuals with 'normal eyesight', and

c. there is wide variation between criteria used by different observers to interpret a given pattern of visual information.

1.4 This report describes experimental tests which have been carried out in the laboratory. No external optics between observer and target was involved in the main tests, thus eliminating systemic effects not connected with the eye-brain system. Laboratory testing was considered preferable to outdoor methods in order to control accurately the large number of parameters involved.

1.5 Three tasks were chosen as a basis upon which to make the comparison. These were

a. The detection of a luminance contrast

b. visual acuity

c. recognition of a silhouette.

Tasks a. and c. are associated with situations likely to be encountered by a soldier, especially at low luminances. They equate most closely with long range observation tasks such as those encountered by observers using telescopes to find low contrast targets against a uniformly illuminated background, eg the horizon. Acuity is a measure of an observer's ability to descriminate detail and is relevant to short range viewing devices such as map readers, stereoscopes and general monitoring instruments.

1.6 Limited studies have been carried out previously for each of the tasks mentioned, eg Campbell and Green (1965) carried out a detection and acuity task at high luminance; Horowitz (1949) studied the acuity task and Davis (1972) compared monocular and binocular vision for recognition and identification of specific objects. The present study was carried out to extend the available results, especially with regard to the lower luminance range, and also to determine the underlying trends involved when comparing monocular with binocular vision generally.

2. Procedure

2.1 The experimental details are given in the appendix. The basic layout is shown in fig 1. 20 observers undertook the experiment which was repeated at 4 luminances for each task.

2.2 The contrast detection task involved a search and, as in the other two tasks, the threshold was taken as the level at which the probability of a correct response was 0.50 (fig 2). Allowance was made for the fact that correct responses were possible by chance alone. Control tests were carried out to ascertain any variation with

a. viewing range

b. stimulus shape, and

c. colour-defectiveness of the observer.

2.3 The acuity task involved the use of Landolt rings (Fig 3a). No search was required by the observer. As before 20 observers were used and a control test was carried out to measure any variation of the results with viewing range.

2.4 The recognition task entailed the measurement of the observer's contrast threshold for the recognition of carefully chosen letters of the alphabet (fig 3b). No search task was required and allowance as made for correct responses. which could have been made by chance alone.

2.5 Emphasis was placed on low ambient luminances in all three tasks for 3 reasons:-

a. Low luminance levels are crucial from a military point of view and put severe limitations on the effectiveness of most passive optical systems.

b. Much of the extra design effort put into producing a direct viewing instrument is concerned with improving its low light level capability eg, larger O.G.s, larger exit pupils, multi-layer coating of components, reduction of veiling glare.

c. The eye's response tends to reach a 'plateau' at higher luminances and changing the ambient light level has very little effect on the eyes's performance.

2.6 Adaptation to the appropriate luminance was achieved by allowing the observer to sit in the conditions to be used for an appropriate period before any results were noted. At starlight levels of illumination an adaptation period of 30 min was necessary. Sufficient preliminary results were taken to allow the observer to adapt to the task at hand, and the total time involved for any one subject was limited to 3 hr in any day.

3. RESULTS

3.1 Discussion

3.1.1 The results for the 3 tasks, including those pertaining to the control experiments, are given in the list of tables. In addition to the numerical results the following subjective effects were noted.

a. 18 out of the 20 observers expressed positive preference for binocular viewing. Subjectively, monocular viewing was most distasteful at the lowest luminances.

b. Observers mentioned fatigue, and requested most frequent rests when viewing at very low luminances.

c. Observers sometimes mentioned the appearance of bright spots of light on the screen. This indicated noise in the visual pathways and was overcome by allowing the subject to rest for a few minutes.

d. There appeared to be minimal correspondence between a subject's confidence in his results and the actual results obtained, except for stimuli which were well above threshold.

3.1.2 Analysis indicates a number of conclusions which can be drawn from the numerical results. The t-test was used at the 0.05 level of significance. The F-test was used in every case to test for equality of variances and where $\sigma_1^2 \neq \sigma_2^2$ a weighted estimate of the number of degrees of freedom was used in the t-test. For a somplete explanation of the methods used, see "Introduction to mathematical statistics" 3rd Edit, by Hoel (1966) published by Wiley.

3.2 Summary

3.2.1 At each luminance for all 3 tasks the binocular threshold was lower than either of the monocular thresholds. Also, in each case the preferred monocular threshold was lower than that of the non-preferred eye.

3.2.2 The monocular/binocular ratios are not affected by changing the viewing distance to infinity.

3.2.3 The degree of binocular superiority in the contrast detection task is not affected by changing the shape of the target from circular to square.

3.2.4 Deuteranopes (colour defectives) did not achieve results which differed significantly from those of the main sample.

3.2.5 For the acuity task, binocular superiority is only marginal at high luminances and increases as the ambient luminance decreases, and as the target to background contrast decreases.

3.2.6 After retabulation of the results from the experimental probability curves it is found that the monocular/binocular ratios are not significantly different when the threshold probability level is increased from 0.50 to 0.75.

3.2.7 Binocular summation for a task involving contrast detection is greater than that expected from probability theory (fig 2), ie the two eyes do not act as mutually independent channels.

3.3 Optical design implications

3.3.1 Apart from the degree of visual comfort afforded to the observer, the main advantage of a binocular instrument lies in the acquisition of low contrast targets.

3.3.2 Spatial resolution enhancement due to binocular viewing is minimal for very high light levels and it is under conditions of high illumination that a biocular could be used with no significant loss of spatial resolution by the observer.

3.3.3 The advantage of using binocular vision in the recognition of low contrast targets is significantly less than that for the simple detection task. However, for long periods of surveillance, a binocular instrument is a necessity simply to maintain the observer's confidence in his performance of a given task.

3.3.4 Using the basic expression for attenuation of a luminance contrast through the atmosphere (Duntley, 1948) a ratio of 1.48 for the monocular/binocular detection ratio (table 1) at daylight luminance can be translated to a binocular advantage factor of 15% over monocular vision in terms of detection range. This result is independent of the meteorological range. For optical instruments involved in long range target acquisition an advantage factor of this order must be considered by the designer.

4. CONCLUSIONS

4.1 Binocular superiority is more marked in the contrast domain than in the spatial frequency domain.

4.2 The measured binocular summation is significantly greater than that expected from simple probability theory.

4.3 Subjective comments, especially during the contrast detection task, indicate that psychologically at least, subjects preferred binocular viewing.

4.4 Measured values of binocular summation are independent of viewing distance.

5. AREAS FOR FURTHER WORK

5.1 The fact that binocular superiority is less for the recognition of a silhouette than for the simple detection task supports the hypothesis that recognition depends both on contrast and structural content of the target. More structurally complex targets may result in significantly different data than those obtained using letters of the alphabet. It is therefore proposed to extend monocular and binocular comparison to realistic targets such as military vehicles.

5.2 Although from the results obtained, the subjective feelings of discomfort and fatigue were not reflected in the measured thresholds, it is proposed to quantify the effect of monocular fatigue by choosing a different performance criterion such as visual search time or ability to make a decision.

ACKNOWLEDGEMENTS

Acknowledgements are due to the volunteer subjects who took part in the experiments and to Dr C Padgham, City University, London, for his advice on the psychophysical methods used.

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Nomenclature

Subscripts MP, MN and B apply to preferred eye, non-preferred eye and binocular viewing. The 'preferred' eye is that which an observer would choose to use when viewing through a monocular instrument. For a 'normal' sighted individual the preferred eye is the master eye.

Standard deviations (denoted by σ) apply to the means to their left in each table.

PLEASE NOTE

Reports quoted are not necessarily available to members of the public or to commercial organisations.

APPENDIX

Details of the experimental apparatus

The basic projection system, shown in fig 1, was the same for all 3 tasks, as follows. A Kodak Carousel remote controlled projector, a, using a nominally rated 250 w lamp projected a 50 x 50 mm transparency on to a white screen. Neutral density filters, b were used to reduce the total light output and a colour filter was used to raise the colour temperature to that of standard illuminant C. A red LED was positioned at the centre of the screen to provide the observer with a reference point. The projector and filters were all housed inside a black box, c, to eliminate stray light.

The distance between the observer and the screen was maintained at 1.3m by the use of a brow pad. The screen subtended 50^o at the observers' eyes. This size was chosen to represent a realistic adaptation field and it corresponds to the apparent field encountered when viewing through a typical military telescope.

Specific details follow.

1.1 The stimuli These were produced by photographically producing negatives of high contrast, and from these making positives on lantern plates, different contrasts being achieved by variation of the development time. A clean cover glass was taped to the emulsion side of each plate to protect the emulsion from scratches. All the slides were cleaned with anti-static fluid to reduce the accumulation of dust.

1.2 Targets

For the contrast detection task the targets were circular grey objects subtending an angle of 200' at the observer's eye. This size was chosen so that the observer was not essentially size limited (Blackwell, 1946; Foxwell and Stevens, 1955); it corresponds to the angular size of a crouching man at 50 ft. The contrasts of the stimuli ranged from 0.01 - 0.30, defining contrast as C where

$$C = \frac{L_o - L_B}{L_B}$$

where L_o is the luminance of the object and L_B the luminance of the background. The targets fell in any of 8 positions about the red reference marker, subtending 8^o to this marker.

The targets for the acuity task were dark Landolt rings with gap sizes ranging from 0.8' to 130' (construction shown in fig 3(a)). A complete range of sizes was constructed at 5 contrast levels, namely 0.7, 0.3, 0.1, 0.03 and 0.01. Each slide contained 4 rings located uniformly about the centre of the slide. The rings on each slide were slightly different sizes, the positions of the gaps appearing randomly in any of 4 positions; top, bottom, right and left. Intermediate positions were not used because acuity can vary with orientation of the stimulus (Campbell, Kulikowski and Levinson, 1966). The very small rings were produced by a double reduction process.

The slides used in the recognition task each contained one of 10 Snellen, non-serif, upper case letters, chosen on the basis of work summarised by Bennett (1965). The letters were chosen to be equally legible to within $\pm$ 10%, and their construction is shown in fig 3(b). It was considered important that each letter could be confused with at least one other eg E with F, P with R, U with V etc. This reduced the possibility that the observer could make a choice based on vague form only.

The letters were projected just below the red central marker at the centre of the screen, ie no search task.

1.3 Field of view

A field of 50° at the observer's eye was chosen for two reasons.

a. It provided a larger adaptive field of view for the observer. A large field approximates to the real life situation and enables the adaptive state of the eye to be accurately specified without the possibility of edge effects near to the target.

b. A large number of optical instruments, especially telescopic sights, have eyepieces with fields of view falling within the range 45-55° and this constitutes the effective adaptive field of the user. In such cases the field luminance changes as a step function at the field perimeter - just as in the experiment.

1.4 Viewing Range

The preferred position of focus of a telescopic eyepiece for a normal sighted observer at daylight illuminations is -0.75D (Poole, 1967). This corresponds to an accommodative distance of 1.3m. Fixed focus military telescopes are designed on this premise.

Achromatic doublets were used in conjunction with wedges to change the apparent viewing distance from 1.3m in the main tests to infinity for the control tests.

1.5 Luminance Range

Duntley (1946) has tabulated the ambient luminances likely to be encountered during an average period of 24 hr. These extend from 3×10^3 down to 10^{-5} Cd M^{-2} at overcast starlight.

All luminance values quoted here were measured using a telephotometer calibrated with respect to an external standard. All measurements of luminance and contrast were made in situ. Variation was achieved by the use of spectrally flat, metal on glass, neutral density filters. By this method the colour temperature of the screen illumination did not change significantly as the luminance was reduced.

The calculated possible error in the luminance measurement is $\pm$ 3.5%. Repeatability of measurements using the telephotometer was within $\pm$ 2% and any inherent errors in the measurement were likely to be in the same direction for a given luminance range on the photometer. So the contrast, being a ratio of two luminances, is estimated to involve an overall error of not more than 5.5%.

Spatial variation of luminance was measured across the screen and it was found that there was a variation of just greater than 25% between the centre and the periphery of the screen. However, within the central 20°, the variation was less than 10% and the mean variation of luminance round the edge of a given stimulus was less than 3.5% ie less than the accuracy obtainable in measuring with the photometer.

1.6 Colour considerations

The tests were designed on a purely black and white basis. Introduction of colour would have involved a much wider programme of work and difficulties would have arisen in the specification of colour contrast. However, it was necessary to control the colour temperature of the projection light, as Levi (1974) has shown that colour temperature can affect the threshold visibility of a stimulus.

Daylight colour temperatures can vary from 5000°K to 10,000°K (Le Grand, 1957) an overcast daylight sky having an average colour temperature of 6400°K (Taylor and Kerr, 1941). In order to maintain a realistic colour temperature which could be easily specified and repeated, standard illuminant C was chosen as the level at which to work. This has a correlated colour temperature of 6740°K and a Chance OB8 filter was used to raise the colour temperature to this level.

1.7 The Observers

Two main requirements were essential. These were that

a. the results of each observer be consistent within themselves, and

b. each observer's results be applicable, within certain limits, to the population to which the results will eventually be applied.

In an attempt to satisfy requirement a. all observers were given an explanation of the tests involved and were allowed a practice run on each task. An important factor was that the observers maintained a high degree of concentration and to this end the observers were not required to undergo testing for longer than 3 hr in any day. Also, rests were allowed at any time during the experiment.

To achieve condition b. all subjects underwent a brief ophthalmic acuity test before commencing the main experiment, and those with at least 6/6 acuity were accepted. The wearing of spectacles was allowed to achieve this level of acuity. Colour defective observers were rejected for the main tests, but 2 deuteranopes were tested as controls.

In this way the observers were coarsely filtered so that nobody took part in the main tests who would have been rejected from military service on the grounds of poor eyesight.

All the observers were untrained in psychophysical tests but the results from trained personnel would not have been expected to have produced significantly different results (Vos, Lazet and Bowman, 1956).

1.8 Procedure

Each subject was given an explanation of the nature of the task before him; this included an explanation of the control for the red LED at the centre of the screen. The subject was required to adjust this marker to his own non-distracting luminance using the rheostat provided.

Observers were told about the method of averting the eyes (or eye) to enhance the detection process at lower luminances (below about 10^{-2} Cd M^{-2}). Practice is required for this method of viewing, and a preliminary run was given before the actual results were recorded.

Before each test a period of adaptation was necessary. This could be a period of up to 30 min. A guide to the required time is given by Duntley (1946).

It was emphasised throughout the tests that the observer was at liberty to rest whenever necessary. The method of response was kept to a simple level so that the observer's response criteria to any task were likely to have minimal effect on the results obtained.

Justification for the methods used was proved by the fact that results were consiste within themselves, and no apparent temporal variation of threshold was found.

TABLE 1

Summary of the Contrast Detection Results

Background luminance ($Cd\ M^{-2}$)	C_{MP}	C_{MN}	C_B	$\frac{C_{MP}}{C_B}$	σ	$\frac{C_{MN}}{C_B}$	σ
1.0×10^{-1}	0.056	0.061	0.038	1.48	0.10	1.61	0.16
0.9×10^{-2}	0.095	0.104	0.063	1.51	0.09	1.66	0.19
1.3×10^{-3}	0.13	0.14	0.08	1.54	0.09	1.72	0.20
4.7×10^{-5}	0.23	0.26	0.17	1.35	0.07	1.53	0.13

TABLE 2

Results of Control Test with Two Observers
Contrast Detection Task with Stimulus at Infinity

Subject	Background luminance ($Cd\ M^{-2}$)	C_{MP}	C_{MN}	C_B	$\frac{C_{MP}}{C_B}$	$\frac{C_{MN}}{C_B}$
RH	1.0×10^{-1}	0.050 (0.050)	0.065 (0.061)	0.032 (0.031)	1.56 (1.61)	2.03 (1.97)
JT	1.0×10^{-1}	0.066 (0.062)	0.074 (0.070)	0.042 (0.040)	1.57 (1.55)	1.76 (1.75)
RH	4.7×10^{-5}	0.23 (0.23)	0.27 (0.28)	0.18 (0.18)	1.29 (1.25)	1.52 (1.53)
JT	4.7×10^{-5}	0.26 (0.26)	0.28 (0.29)	0.20 (0.20)	1.32 (1.30)	1.40 (1.47)

(Results obtained at 1.3m shown in parenthesis)

TABLE 3

Results of Control Test with two Observers
Contrast Detection Task with a Square Stimulus

Subject	Background luminance (Cd M^{-2})	C_{MP}	C_{MN}	C_B	$\frac{C_{MP}}{C_B}$	$\frac{C_{MN}}{C_B}$
RH	1.0×10^{-1}	0.048 (0.050)	0.058 (0.061)	0.030 (0.031)	1.60 (1.61)	1.93 (1.97)
JT	1.0×10^{-1}	0.064 (0.062)	0.072 (0.070)	0.040 (0.040)	1.60 (1.55)	1.80 (1.75)
RH	4.7×10^{-5}	0.23 (0.23)	0.28 (0.28)	0.18 (0.18)	1.25 (1.25)	1.54 (1.53)
JT	4.7×10^{-5}	0.26 (0.26)	0.28 (0.29)	0.20 (0.20)	1.30 (1.30)	1.38 (1.47)

(Results obtained with a circular stimulus shown in parenthesis)

TABLE 4

Results Obtained for the Contrast Detection Task
By Two Colour Defective Observers (Deuteranopes)

Subject	Background Luminance (Cd M-2)	C_{MP}	C_{MN}	C_B	$\frac{C_{MP}}{C_B}$	$\frac{C_{MN}}{C_B}$
NC	1.0 x 10-1	0.054	0.060	0.038	1.42	1.58
NC	0.9×10^{-2}	0.10	0.11	0.065	1.54	1.66
NC	1.3×10^{-3}	0.12	0.14	0.082	1.50	1.67
NC	4.7×10^{-5}	0.22	0.26	0.17	1.36	1.56
JM	1.0×10^{-1}	0.072	0.084	0.046	1.57	1.83
JM	0.9×10^{-2}	0.12	0.13	0.075	1.53	1.72
JM	1.3×10^{-3}	0.13	0.15	0.088	1.52	1.70
JM	4.7×10^{-5}	0.24	0.28	0.18	1.38	1.57

TABLE 5

Summary of Acuity Results
(A is acuity in minutes $^{-1}$)

Background luminance (Cd M^{-2})	A_{MP}	A_{MN}	A_B	$\frac{A_B}{A_{MP}}$	σ	$\frac{A_B}{A_{MN}}$	σ
CONTRAST = 0.70							
7.1	0.97	0.94	1.02	1.06	0.08	1.08	0.07
1.0×10^{-1}	0.45	0.43	0.50	1.11	0.09	1.18	0.10
3.4×10^{-3}	0.09	0.09	0.10	1.12	0.15	1.17	0.16
3.6×10^{-4}	0.06	0.06	0.07	1.15	0.09	1.23	0.09
CONTRAST = 0.30							
7.1	0.81	0.79	0.87	1.07	0.07	1.10	0.09
1.0×10^{-1}	0.23	0.22	0.27	1.19	0.11	1.23	0.14
3.4×10^{-3}	0.06	0.06	0.08	1.22	0.11	1.35	0.19
3.6×10^{-4}	0.027	0.026	0.034	1.23	0.07	1.33	0.11
CONTRAST = 0.10							
7.1	0.22	0.21	0.26	1.18	0.18	1.26	0.18
1.0×10^{-1}	0.07	0.06	0.09	1.27	0.13	1.41	0.17
3.4×10^{-3}	0.018	0.015	0.024	1.39	0.13	1.61	0.15
3.6×10^{-4}	0.013	0.011	0.017	1.38	0.08	1.64	0.10
CONTRAST = 0.03							
7.1	0.09	0.09	0.12	1.27	0.13	1.39	0.21
1.0×10^{-1}	0.023	0.020	0.033	1.42	0.14	1.61	0.18
CONTRAST - 0.01							
7.1	0.013	0.011	0.017	1.37	0.08	1.54	0.10

TABLE 6

Results of Control Test with Two Observers
Acuity Measured with Stimulus at Infinity

Subject	Stimulus Contrast	A_{MP}	A_{MN}	A_B	$\frac{A_B}{A_{MP}}$	$\frac{A_B}{A_{MN}}$
Luminance = 7.1 Cd M^{-2}						
IB	0.70	0.99 (1.01)	0.90 (0.92)	1.04 (1.07)	1.05 (1.06)	1.16 (1.16)
RH	0.10	0.23 (0.24)	0.23 (0.23)	0.25 (0.26)	1.09 (1.08)	1.09 (1.13)
IB	0.03	0.10 (0.10)	0.09 (0.10)	0.14 (0.14)	1.40 (1.40)	1.56 (1.40)
Luminance = 3.4×10^{-3} Cd M^{-2}						
IB	0.70	0.10 (0.10)	0.09 (0.10)	0.10 (0.10)	1.00 (1.00)	1.11 (1.00)
RH	0.30	0.06 (0.06)	0.05 (0.05)	0.07 (0.07)	1.17 (1.17)	1.40 (1.40)
RH	0.10	0.013 (0.015)	0.013 (0.014)	0.020 (0.023)	1.54 (1.53)	1.54 (1.64)

(Results obtained at 1.3 m shown in parenthesis)

TABLE 7

Summary of Recognition (Contrast Threshold) Results

Background luminance (Cd M^{-2})	R_{MP}	R_{MN}	R_B	$\frac{R_{MP}}{R_B}$	σ	$\frac{R_{MN}}{R_B}$	σ
7.1	0.020	0.022	0.016	1.30	0.19	1.45	0.19
1.0×10^{-1}	0.067	0.072	0.050	1.33	0.09	1.43	0.09
3.4×10^{-3}	0.22	0.23	0.16	1.34	0.15	1.43	0.17
3.6×10^{-4}	0.47	0.49	0.38	1.27	0.14	1.32	0.18

FIG.1

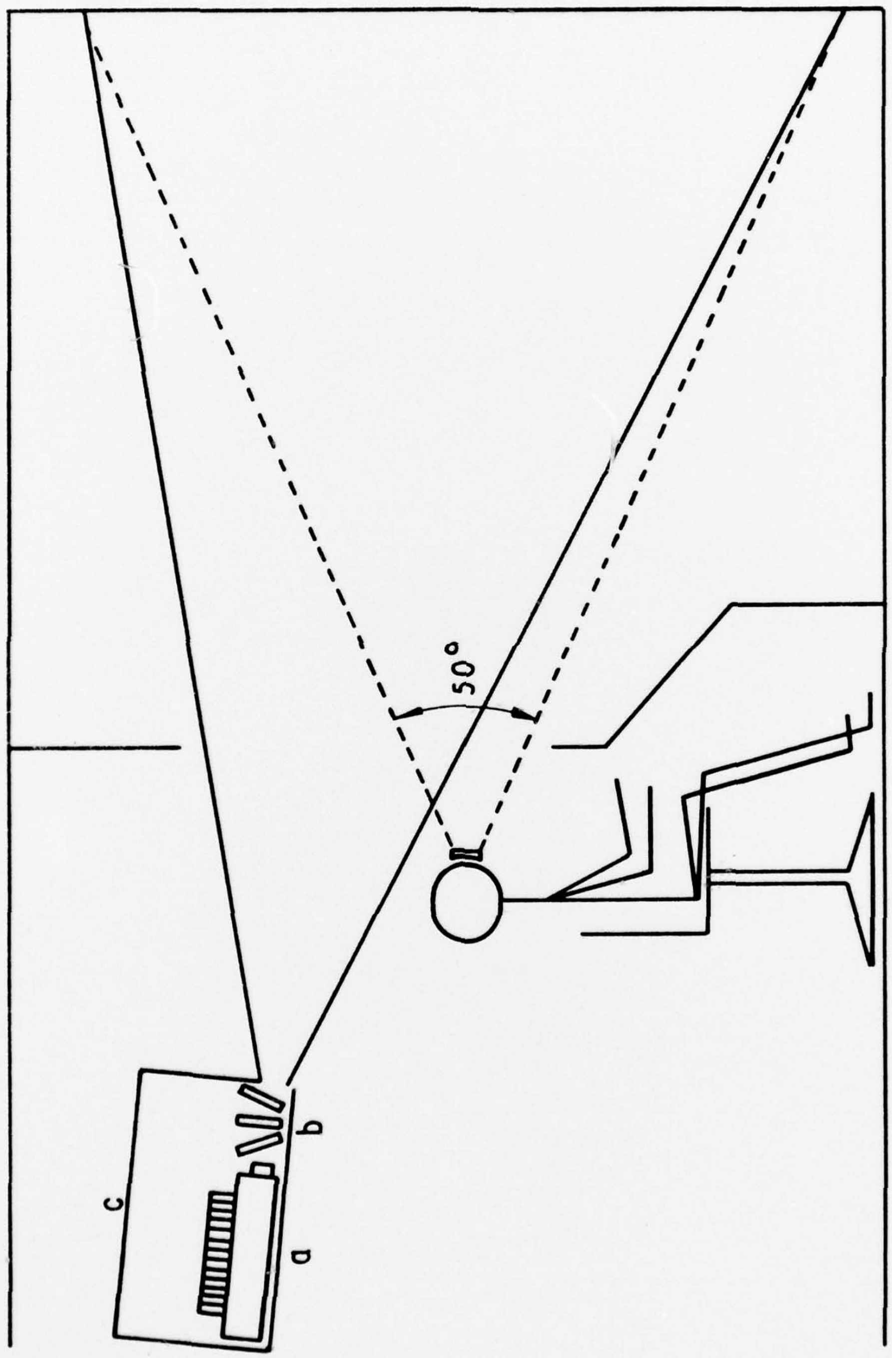

FIG.1 PROJECTION SYSTEM

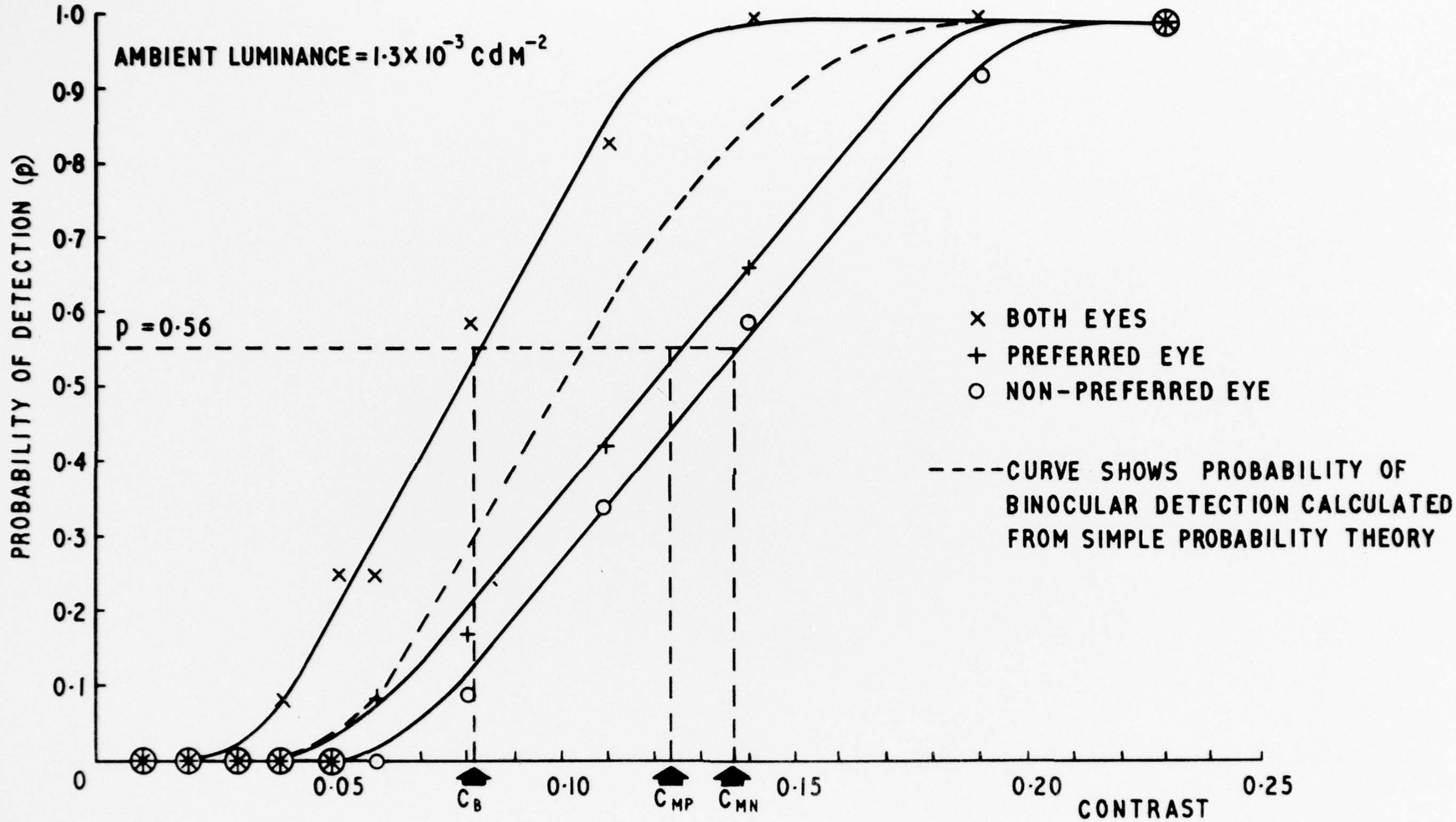

FIG.2 RESULTS OF SUBJECT (N.C) VIEWING A 200′ ARC DARK OBJECT ON A LIGHT BACKGROUND

FIG.2

FIG. 3(a) LANDOLT RING

D	E	F	H	N
0.95	1.09	1.04	1.02	0.97
P	**R**	**U**	**V**	**Z**
1.01	0.91	1.08	0.94	1.05

RELATIVE LEGIBILITIES AS LISTED BY BENNETT (1965)

FIG. 3(b) NON - SERIF LETTERS USED IN THE RECOGNITION TASK

DOCUMENT CONTROL SHEET

(Notes on completion overleaf)

Overall security classification of sheet ....UNCLASSIFIED..

(As far as possible this sheet should contain only unclassified information. If is is necessary to enter classified information, the box concerned must be marked to indicate the classification eg (R),(C) or (S)).

1. DRIC Reference (if known)	2. Originator's Reference RARDE Technical Report 2/77	3. Agency Reference	4. Report Security Classification UNLIMITED
5. Originator's Code (if known) 851600	6. Originator (Corporate Author) Name and Location Royal Armament Res & Dev Est Ministry of Defence, UK		
5a. Sponsoring Agency's Code (if known)	6a. Sponsoring Agency (Contract Authority) Name and Location		

7. Title

Experimental assessment of monocular and binocular vision

7a. Title in Foreign Language (in the case of translations)

7b. Presented at (for conference papers). Title, place and date of conference

8. Author 1, Surname, initials	9a Author 2	9b Authors 3, 4...	10. Date / pp / ref
HOME R			6. 1977 / 18 / 14
11. Contract Number	12. Period	13. Project	14. Other References

15. Distribution statement

No limitations

Descriptors (or keywords)

Visual perception Discrimination Target discrimination Luminance Acuity Visual acuity Recognition Contrast Target recognition Binocular vision Monocular vision

(TEST except last entry)

continue on separate piece of paper if necessary

Abstract

Subjective tests using monocular and binocular vision have been carried out to measure detection, acuity and recognition capabilities over a range of ambient luminances from 4.6×10^{-5} to $7.1\ Cd\ m^{-2}$. Maximum binocular superiority is evident in the region of contrast threshold, the binocular threshold being as much as 30% lower than either of the monocular thresholds. The ratio of binocular : monocular acuity is much lower for high contrast targets, binocular superiority being about 6% at high luminance. This figure steadily increases with reducing contrast and luminance. The practical significance of the results is that binocular instruments have a maximum advantage over monoculars under low luminance conditions when the observer is attempting to acquire low contrast targets.

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Subjective tests using monocular and binocular vision have been carried out to measure detection, acuity and recognition capabilities over a range of ambient luminances from 4.7×10^{-5} to 7.1 Cd M^{-2}. Maximum binocular superiority is evident in the region of contrast threshold, the binocular threshold being as much as 30% lower than either of the monocular thresholds. The ratio of binocular : monocular acuity is much lower for high contrast targets, binocular superiority being about 6% at high luminance. This figure steadily increases with reducing contrast and luminance. The practical significance of the results is that binocular instruments have a maximum advantage over monoculars under low luminance conditions when the observer is attempting to acquire low contrast targets.

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